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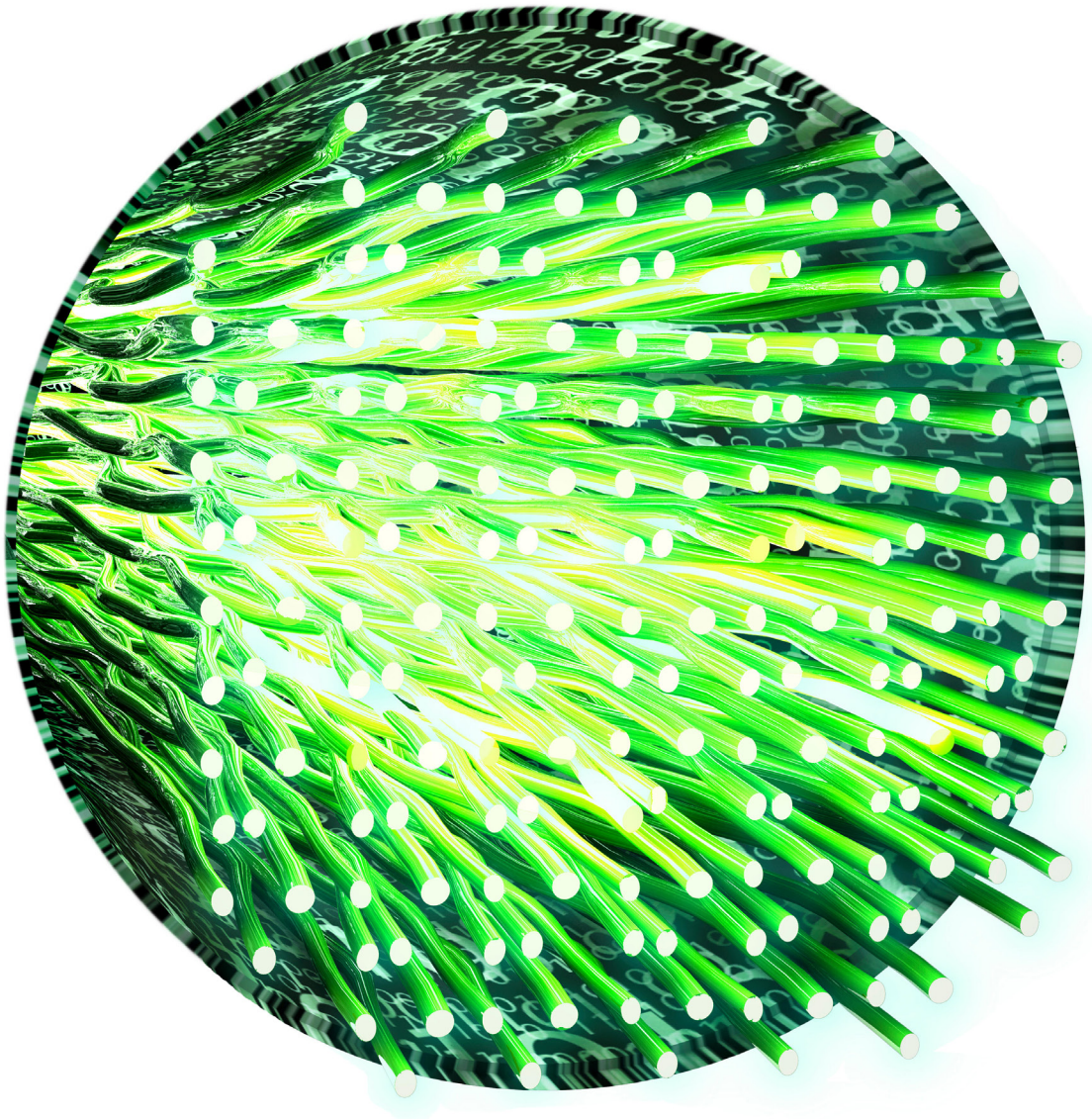


Communications infrastructure upgrade

The need for deep fiber

Published July 2017

Executive summary

Fifth generation mobile networks (5G) are now poised for field testing and launch worldwide. The technology unlocks unprecedented potential to build seamless digital ecosystems, reshaping the way citizens live, work, and interact.

Wireless networks were at a similar inflection point as 4G services launched early in the decade. The United States took action as government made new spectrum available and carriers responded to accommodate radical, twenty-fold growth in global mobile data traffic. The massive investment in wireless network infrastructure rewarded the US consumer with more coverage at affordable prices, and the US economy generated up to 700,000 jobs as a result.[1]

An equally transformative moment is coming with 5G, but with two important differences. First, the economic stakes are potentially much higher, where connected devices, applications and business models could dramatically stimulate economic productivity. Second, the United States is not as well prepared to take full advantage of the potential, lacking needed fiber infrastructure close to the end customers (deep fiber).

Communications infrastructure upgrade
The need for deep fiber

Deep fiber is the next front in the battle to lead the world in Internet speed and capacity

Unlocking the full potential of 5G in the United States rests on a key assumption: the extension of fiber deep into the network. Despite the demand and potential economic benefits of fiber deployment, the United States lacks the fiber density in access networks to make the bandwidth advancements necessary to improve the pace of innovation and economic growth. Increased speed and capacity from 5G will rely on higher frequencies and network densification.[2, 3] Carriers will deploy many more small cells, homespots, and hotspots in higher bands, with a coverage radius measured in meters versus kilometers. Without more deep fiber, carriers will be unable to support the projected four-fold increase in mobile data traffic between 2016 and 2021.[4]

A second motivation for "deep fiber" deployment is to increase broadband service choice for residential and business customers. Deep fiber is a key tool for the national infrastructure imperative to provide consumers high-speed broadband connections no matter where they live at prices they can afford, closing the "digital divide."

Wireline broadband access supports as much as 90 percent[5] of all Internet traffic even though the majority of the traffic ultimately terminates on a wireless device. However, twelve years after the first fiber to the home (FTTH) deployments, only 38 percent of homes have a choice of two providers offering speeds of at least 25 Mbps.[6] In rural communities, only 61 percent of the population have access to 25 Mbps wireline broadband, and when they do, they can pay as much as a three times the premium over suburban customers.[7]

To meet future broadband needs, the United States needs an estimated $130–150 billion of fiber infrastructure investment

A Deloitte Consulting LLP analysis estimates that the United States requires between $130 and $150 billion over the next 5–7 years to adequately support broadband competition, rural coverage and wireless densification. Such ambitious infrastructure investment could derive from a variety of sources including communications service providers, financial investors and public-private partnerships.

Our estimates include funding for three broad categories of fiber deployment: fiber for wireless densification, fiber to increase consumer and business broadband competition and fiber to serve rural/underserved geographies. Moreover, our models suggest massive synergies between the build required for wireless densification and adding broadband competition in urban areas. There are also additional benefits between densification and underserved communities. With more than 60 percent of total costs for construction, permits and design,[8] fiber providers may need to share last mile access routes and rights of way where possible to realize such synergies.

The current wireline industry construct does not incent enough fiber deployment

Some wireline carriers are reluctant or unable to invest in fiber for the consumer segment despite the potential benefits. Expected wireline CAPEX ranges between 14–18 percent of revenue. Wireline OPEX can be 80 percent of revenue.[9] Fiber deployment in access networks is only justified today if a short payback period can be guaranteed, a new footprint is being built, repairs from rebuilding after a storm or other event justifies replacement, or in subsidized geographies where Universal Service funds can be used.

The largest US wireline carriers spend, on average, five to six times more on operating expenses than capital expenditures.[10] Excessive operating expenditures caused, in part, by legacy TDM network technology restrict carriers' ability to leverage digital technology advancements. Worse, as legacy TDM networks continue to descale, the percentage of fixed costs overwhelms the cost structure leading to even greater margin pressure.

In the last five years, wireline carriers have lost seven points of market share in broadband access, mainly to cable operators. Cable operators, who have the advantage of a more modern coax network, do not have these legacy constraints and have aggressively deployed high-speed broadband access using DOCSIS 3.0 and 3.1 upgrades. Cable operators currently cover more than 85 percent percent of US homes with Internet speeds of 25 Mbps or greater.[10]

Generating sufficient cash flow to motivate fiber upgrades means building a business model based on simplicity and capital productivity. This will not happen without completing the migration from TDM to an all-IP network. The complexity imposed on IP services by legacy product iteration and cumbersome IT systems increases operational costs, drives up failure rates, and leaves customers unhappy.

- Mobile operators, not required to support legacy services, require approximately one-eighth the care staff and receive half as many inbound calls per customer compared to wireline network operators.[11]
- A survey by Nemertes Research found a reduction in average time to repair from 21 hours to 5 hours for a single, end-to-end IP network.[12]
- French wireless and wireline provider, Iliad, operates an all IP network with approximately 3 to 4 employees per 10,000 customers compared to 12 to 15 employees per 10,000 customers for US providers.[13, 14]

Carriers stand to gain tremendous efficiency from deploying new IP networking architectures like Software Defined Networks (SDN) and Network Function Virtualization (NFV). This technology is also important to provide the scale and elasticity required to support 5G networks in the future. However, the requirement to operate and maintain legacy networks and systems (TDM based) limits carriers' ability to take advantage of the savings and shift capital to deep fiber deployment.

Carriers and policymakers can share responsibility for motivating investment in fiber

The lack of funding and motivation to deploy fiber leaves the future of wireless and wireline connectivity uncertain. Wireline telecommunications companies are choosing to invest in areas other than fiber deployment including satellite TV, advertising, content and advanced business services. Similarly, infrastructure funds and REITs have made few investments in telecommunications assets. Many wireline carriers depreciate 1.2x–1.3x as much PPE as they add in a given year, leaving a declining net asset base to service increased demand.[15]

Many countries, including the United States, prioritize ubiquitous affordable broadband as a policy objective. The United States ranks tenth in the world for average broadband speed and percentage of users with over 25 Mbps.[16] This is remarkable, as the United States has almost six times the cumulative land area of the nine countries ranked above it. Removing legacy regulations that constrain competition and investment may enable market forces to solve many of the deep fiber and broadband coverage challenges in the United States. Furthermore, empowering market forces may enable the government to focus on a more limited set of geographies that are very expensive to serve or have low income/affordability issues.

Carriers should consider:

- Establishing deep fiber as a top priority investment for the long term.
- Redesigning business models and processes based on digital sales and care channels.
- Providing a more limited set of standard IP products to substitute legacy TDM products.

US policymakers should consider:

- Eliminating regulatory barriers that prevent carriers from operating a single IP network, impede deployment of additional fiber assets, or restrict the types of services that may be offered.
- Avoiding regulation that limits carrier innovation in creating new monetization mechanisms or voluntary sharing of deep fiber and associated communications infrastructure such as trenches, conduit, rights of way and cell sites.
- Dispersing Universal Service support more efficiently to coordinate/encourage deep fiber programs.

Reforms to the Universal Services Administrative Company (USAC) to improve operational efficiency is a prerequisite to implement a coordinated deep fiber program. Recently, USAC has come under growing criticism regarding its operations and the resulting impact to end-users, such as consumers, schools, libraries and companies. Meanwhile, USAC's internal expenses are growing approximately at 12 percent per year.[17] In the past, the Federal Communications Commission (FCC) has considered putting USAC's operations out for competitive contract to save costs and improve responsiveness to organizations seeking funds to close the digital divide. At minimum, reforming USAC internal operations seems warranted to meet broader goals of expanding fiber infrastructure and addressing rural Internet access.

New monetization mechanisms needed to encourage deep fiber investment

Important as they are, IP migration and regulatory reforms will not be enough to create the financial case for deep fiber deployment that is needed for broadband and densification. Wireless, wireline and cable require creative new ways to monetize "last mile" access as an incentive for massive fiber deployment. We contemplate three potential models:

Synergies between deep fiber and adjacent services in an 'unlimited' world
Gartner predicts that affluent households will have up to 500 connected devices by 2022.18 In some cases, IoT services offer the prospect of new revenue, however, most connected devices will require low bandwidth or be WiFi enabled and, therefore, may not provide carriers with incremental revenue. In such cases, carriers have an opportunity to increase revenue by offering integration, network security, and traffic management services within the increasingly complex mix of IoT devices and ecosystems.

Partnership between carriers and OTT players to fund deep fiber
As limited fiber availability constrains increased wireless densification and fiber broadband, over the top players may choose to fund fiber deployment, including owning assets or forming partnerships with carriers.

Deep fiber as a financial investment
Insufficient supply of deep fiber and overwhelming demand growth are strong fundamentals for fiber investment. As interest grows from non-traditional fiber investors, we expect shared infrastructure models to emerge for last mile fiber access. Fiber as leased real estate could allow carriers to maximize asset utilization.

Carrier investment and regulatory reform can provide key ingredients to address the deep fiber shortage. As carriers are already making 5G investment decisions, fiber investment is top of mind. Lack of action may lead carriers to commit to investments inconsistent with the goal of better densification, broadband competition and closing the digital divide.

Reforming USAC's internal operations seems warranted in order to meet broader goals of expanding fiber infrastructure and addressing rural Internet access.

Introduction

Fiber is the centerpiece of wireless advancement

Wireless networks were at an inflection point as 4G services launched early in the decade. "More spectrum and faster networks" became the rallying cries of consumers, carriers and governments alike in the global competition to lead in wireless Internet speeds. The world responded, increasing wireless speeds and capacity to accommodate an 18-fold increase in global mobile data traffic and a 21-fold increase in average mobile data speed since 2011.[4, 19]

How the US inspires the next round of network infrastructure investment will determine whether it continues to lead the world in achieving even greater innovation.

The United States, in particular, took action. Since 2008, the US government has made 295MHz of licensed spectrum[20] available. In the past 8 years, mobile data usage soared from 0.2 GB per month to 2.5 GB per month[21] and in many cases much higher. During the same period, the postpaid ARPUs of major US wireless carriers remained relatively flat, implying price per GB declined by 10–15 percent.[22, 23] As price per GB has declined, carriers have added spectrum and made cost reductions to help keep pace.

Carriers and the federal government made good on economic contributions Deloitte postulated in its 2011 and 2014 papers that 4G drove billions of infrastructure investment between 2012-2016 likely resulting in the upper bounds of the projected ranges of $73–151 billion in GDP growth and 371,000–771,000 new jobs.[1]

5G wireless has a wireline pulse

Another inflection point is coming with 5G. But this one is different. While 5G standards focus on a new generation of technology and capabilities for speed and flexibility to connect the "Internet of things," provide mobile broadband, and supply critical communications, the lifeblood of its potential will come from the wireline network with the ultimate goal to extend fiber deep into the network near the customer. Deep fiber also supports the national infrastructure imperatives of increasing choice between providers for residential and business consumers and closing the digital divide.

How the United States inspires the next round of network infrastructure investment will likely determine whether it continues to lead the world in even greater innovation, getting more people connected to faster networks, and bringing them the content they need at prices they can afford.

Extending fiber deeper into communities is a critical economic driver, promoting competition, increasing connectivity for the rural and underserved, and supporting densification for wireless.

Deep fiber is at the center

Network infrastructure plays a prominent role in economic growth and innovation.

Fiber density is critical to support the next round of innovation and Internet access for America. Deep fiber can facilitate high-speed access to more homes, more businesses and support hundreds of thousands of new cell sites and hot spots for 4G and 5G.

Previous generations of wireless technology (i.e., 3G and 4G) relied on broader blocks of spectrum and improved spectral efficiency to generate higher speeds and increased capacity. Increased speed and capacity from 5G will rely more heavily on the use of higher frequencies and densification.[2, 3] Deploying fiber closer to the customers (i.e. deep fiber) can enable efficient transport of increased wireless traffic from that densification.

Carriers are already purchasing and testing high-frequency spectrum (both licensed and unlicensed) to solve capacity constraints. Rather than building macro towers with mid or low band spectrum, carriers will deploy lower powered small cells and rely on homespots and hotspots each with a coverage radius measured in meters versus kilometers. Densification of access points with small coverage areas imply that fewer users share the network capacity produced by 4G or 5G small cells, generating enormous performance gains.

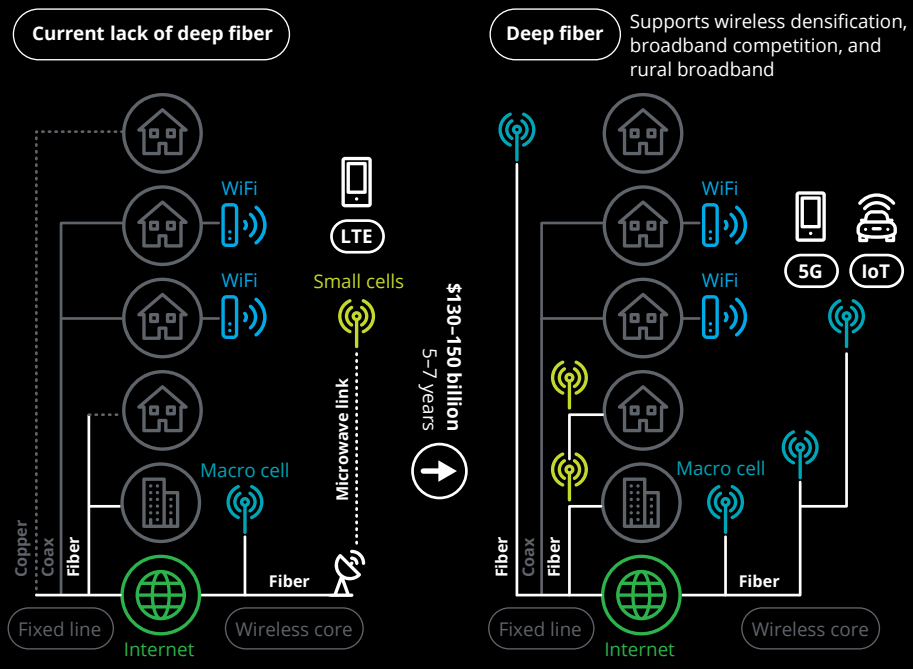
Transmission at higher frequencies exhibits more limited propagation characteristics than transmission at lower frequencies. The signals cannot reach as far and have more difficulty penetrating walls or other barriers. Therefore, network densification becomes an even greater imperative. Such densification is challenged, given current fiber deployment limitations and the upgrade costs and deployment cycle times associated with traditional network architecture. Small cells need connections to fiber/cable backhaul to realize capacity and speed potential.

Homespots and hotspots require high-speed broadband connections to homes and business. Without deeper fiber deployment, carriers will be unable to support the projected four-fold in mobile data traffic increase between 2016 and 2021.[4]

Exhibit 1 below shows how fiber is a critical component to realizing opportunities for the economy as it expands into communities to promote competition, increases connectivity for the rural and underserved, and supports densification for wireless.

Exhibit 1

Illustrative view of deep fiber deployment



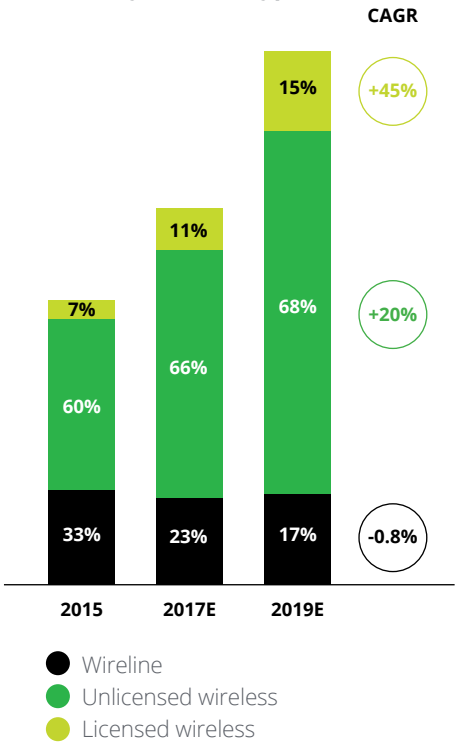
A second motivation for "deep fiber" deployment is to increase broadband service choice for residential and business customers

Wireline broadband access is the unsung hero of our nation's communications infrastructure. While a majority of Internet traffic terminates on a wireless device, nearly all of that traffic relies on home WiFi access points, homespots, and hotspots connected to wireline broadband infrastructure services such as fiber, coax, or twisted-pair copper. Wireless networks only carry 11 percent of traffic, implying wireline networks support nearly 90 percent of total Internet traffic.

Today the bulk of the traffic carried by these wireline broadband networks is video for entertainment and information purposes. Streaming video and new forms of immersive media such as Augmented and Virtual Reality (AR/VR) will contribute to traffic growth estimated at 181 percent CAGR through 2020.[25] In addition to these new use cases, there will also be a massive increase the number of devices, pressuring both WiFi and Cellular networks to support the massive number of simultaneous devices per base station. Without sufficient fiber networks, innovation in new use cases, new applications and new devices will likely be stifled. Deep fiber deployment is the crux of the new capacity required, including fiber to the home/business and fiber backhaul to support wireless densification.

In addition to supporting wireless capacity growth, wireline bandwidth to individual homes and businesses will likely become even more essential over the next half-decade. Fiber to the home and business will be necessary to support the future of content delivery including video, gaming, AR/VR, and other yet-to-be-invented new content and application platforms. Fiber is anticipated to be the next front in the battle to lead the world in Internet speed and capacity, across both wireline and wireless networks.

Exhibit 2
US traffic by network type[24]



Fiber is the next front in the battle to lead the world in Internet speed and capacity, both for wireline and wireless networks.

Despite the demand and economic case for deployment, the United States lacks the fiber density to make the capacity and bandwidth advancements necessary to improve the pace of innovation and economic growth

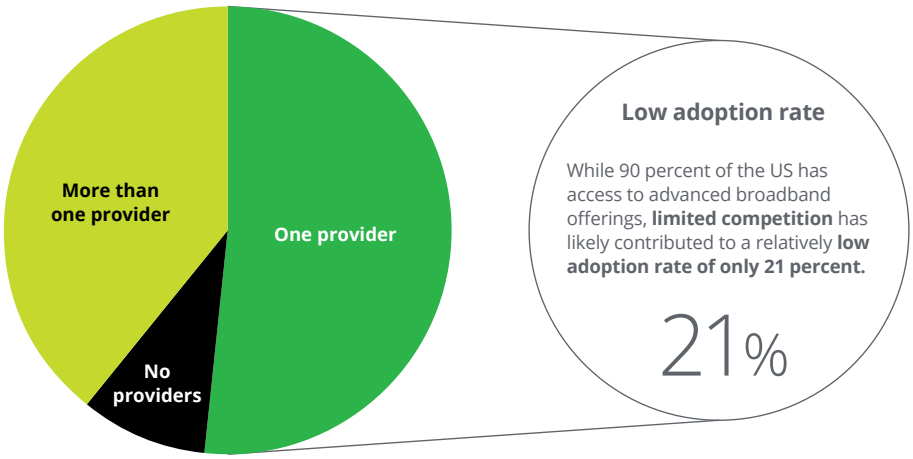
Carriers will not be able to take advantage of WiFi offload to decrease wireless traffic without more deep fiber to transport all that potential new traffic.

FTTH deployments in the United States began in 2005 with Verizon's introduction of its fiber optic TV service in Keller, TX to 9,000 initial customers.[26] More than 12 years later, wireline telecom companies pass approximately 26 million houses with fiber—less than 20 percent of total US houses.[27, 28] Telecom companies serve the remaining 70 percent with slower copper technologies, including Fiber to the Node (FTTN) or DSL, and in some cases, offer no broadband services at all. Cable has been aggressive in deployment of high-speed broadband access using DOCSIS 3.0 and 3.1 upgrades. Cable companies currently cover more than 85 percent percent of US homes with Internet speeds of 25 Mbps or greater, the FCC definition for broadband communications services.[29, 30, 31]

Although a vast majority of US homes receive 25 Mbps or faster, many homes are still left underserved from a speed and competitive-choice perspective. Most homes in the United States have few options for broadband Internet access at speeds of 25 Mbps down and 3 Mbps up (25/3 Mbps), as shown on the right-hand side of Exhibit 3 below. Given the limited competition in most of the country and the resulting low pressure on pricing, there has been limited adoption.

Existing FTTH and DOCSIS broadband networks differ from the architecture needed to support widespread small cell densification. Small cells will require dedicated fiber pairs, and thus necessitate a higher fiber count. Conversely, fiber to the home is architected to maximize the amount of fiber shared between subscribers. Without access to additional high-speed broadband and fiber tailored for small cells, carriers lack the economic incentive to deploy small cells. Moreover, it is unlikely that carriers will take advantage of WiFi offload to decrease wireless traffic without more deep fiber to transport all that potential new traffic.

Exhibit 3
Consumer choice for 25/3 Mbps service[6]



The digital divide continues to widen

The lack of fiber and/or competitive broadband worsens in rural and underserved communities

Access to broadband across different geographies is uneven at best. Urban America has better access to broadband and is improving its access at a faster rate than rural and underserved communities. On average, 90 percent of Americans have access to 25/3 fixed broadband; only 61 percent of the rural population have access to 25/3 fixed broadband.[6] The difference in this broadband access between houses in urban and rural communities and those who are traditionally underserved is what defines the digital divide.

There are almost 21,000 wire centers in the United States serving approximately 133 million households, and a territory of almost 3.5 million square miles. Most of the population live in high-density urban and suburban areas served by just over 6,000 wire centers that cover almost 84 million households but represent less than 110,000 sq. miles. These wire centers typically enjoy faster broadband and more competition than the remaining 17,000 wire centers that serve sparsely populated and more remote areas.

These remaining 15,000 wire centers can be divided into rural and extremely rural geographies. There are approximately 1,100 rural wire centers serving about 28 million households and over 13,000 extremely rural wire centers serving 21 million households. The typical rural wire center is 100 sq. miles and serves 6,500 households. The typical extremely rural wire center serves 200–250 sq. miles and serves around 1,600 households. Generally, the layout of these geographies is a small town containing approximately 80 percent of all the households and businesses in an area of 2–5 sq. miles and a sparse rural population in the remainder of the wire center.[32]

In these rural or extremely rural wire centers, if there is broadband competition, it is usually in the form of a cable company or a CLEC offering service in only the town center, effectively ignoring the outlying portions of the wire center. Usually this service has an effective monopoly as incumbent telecom carrier (ILEC) has poor market share and an aging network. Carrier of last resort obligations force ILECs to serve the entire wire centers, while cable companies and CLECs can focus on the relatively densely populated town centers (see Exhibit 5).

Competitive losses to cable and CLEC triple play offerings often devastate ILEC economics in these areas, preventing them from providing a competitive broadband offering in the town center or addressing the outlining areas of the wire center. Although fiber is not required for wireless densification, deep fiber is still essential to serve these very rural areas with broadband speeds that meet the national standard, and have a choice of providers.

In the absence of competition, and given the aging, less efficient TDM network, broadband in rural areas is typically far more expensive than in urban and suburban environments. For example, in a sample Kansas wire center, the CLEC charges $45 for 15 Mbps, $135-160 for 100 Mbps and $28 for voice service. This compares to a suburban wire center served by two providers able to offer 25 Mbps or higher in which 60Mbps is $45 and 100 Mbps is $55 with voice an additional $10 more. Thus, rural prices for 100 Mbps Internet and voice are almost three times as much as in the suburban example.[33] This pattern of higher prices and unserved outlying areas is repeated across the country.

Exhibit 4
Broadband availability in rural and urban areas (2016)[6]

Level of Availability	Nationwide	Urban	Rural
No provider	10%	4%	39%
One provider	51%	52%	48%
More than one provider	39%	44%	13%

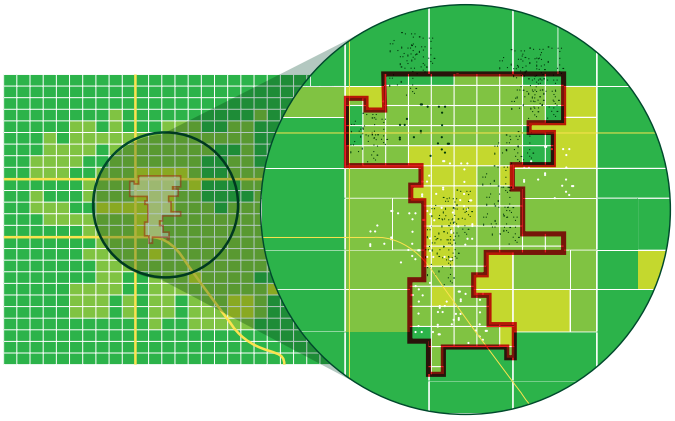
Exhibit 5
Wire center visual

Typical rural wire centers consist of a small town **with ~80% of the population in ~10% of the territory.**

ILECS are forced to serve entire geography.

Competitive connectivity providers typically serve only the town center.

Such a scenario challenges ILEC economics and broadband coverage outside the town center.



**This is a representative depiction of a rural wire center, where lighter shades indicate higher population density.*

Major fiber investment is needed

To meet future broadband needs, the United States needs an estimated $130–150 billion of fiber infrastructure investment

Deloitte Consulting LLP analysis estimates that the United States requires $130–150 billion of fiber investment in the next 5–7 years to support broadband competition, rural coverage and wireless densification. Such ambitious infrastructure investment could derive from a variety of sources including traditional communications service providers, financial investors and public-private partnerships. Our estimates include funding for three broad categories of fiber deployment:

Fiber for wireless densification
Estimated fiber costs for wireless densification assume that a majority of densification occurs in the most populated metropolitan areas, covering approximately 48 percent of the total US population. To gain efficiencies, we assume that multiple wireless carriers will share fiber backhaul or conduit to small cells, rather than each carrier building out its own. Our cost models also take into consideration the significant differences in construction costs based on population density as we approximate fiber deployment costs for five categories of population concentration.

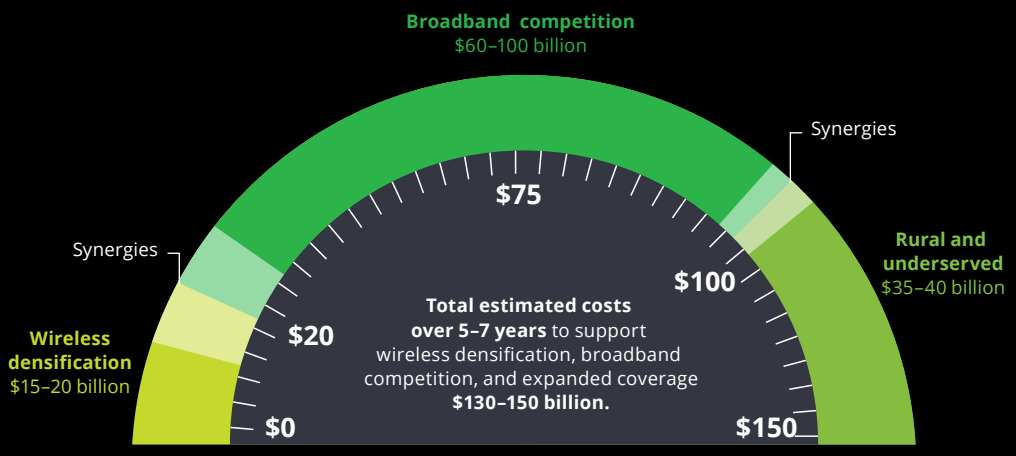
Fiber to increase broadband competition
Competition between at least two providers that meet federal guidelines for broadband of 25 Mbps downlink and 3Mbps uplink implies improving broadband speeds to about 55 million urban suburban houses as well as approximately 13 million rural houses.[34] Our cost estimates assume that 75 percent of these 70 million homes receive fiber to the home, while the remaining 25 percent receive wireless (5G) or other technologies that can cost effectively yield broadband speeds greater than the minimum federal requirements.

Rural/underserved geographies
Approximately 10 million rural homes and 3 million urban/suburban homes do not have broadband of at least 25 Mbps.[34] Given the costs associated with deploying high speed broadband to these geographies, we have based our estimates on the use of alternative technologies such as fixed wireless (LTE or 5G) and fiber to the node, using advanced modulation and vectoring.

Regardless, fiber will still play a critical role. Whether to supply backhaul to wireless towers or to shorten copper distances, closing the digital divide requires fiber investment in these underserved areas.

As depicted in Exhibit 6, we also account for synergies between the three categories of fiber deployment described above. For example, there are massive synergies between the build required for wireless densification and adding broadband competition in urban areas. Since more than 60 percent of total costs are for construction, permits and design, it is imperative that fiber providers can share last mile access routes and rights of way.

Exhibit 6
Required fiber infrastructure investment



Incentives to deploy fiber are lacking

The current wireline industry construct does not incent sufficient broadband deployment

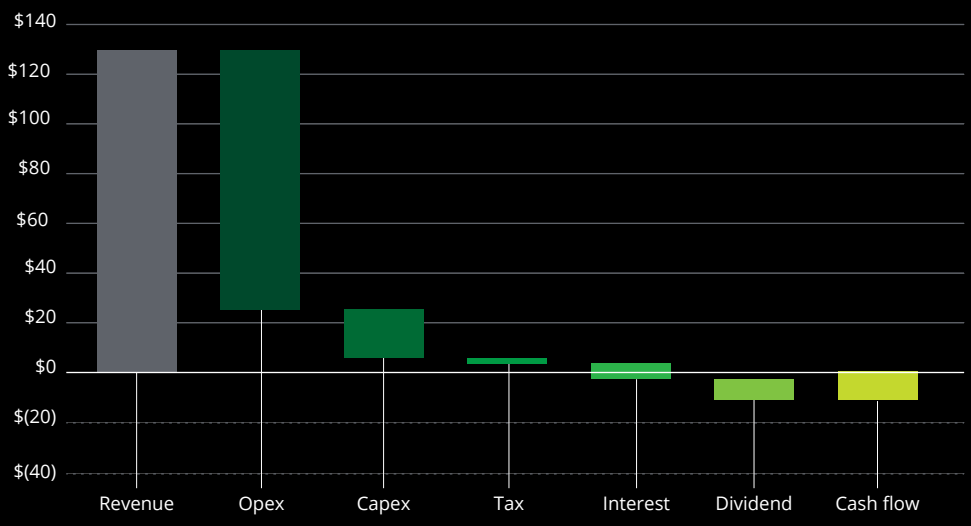
Strong demand for fiber exists from wireless densification for 5G, improved broadband access and new business connectivity services. As established in the previous section, such demands remain either unmet or are unevenly served across much of the United States. What are the barriers preventing carriers from making the necessary investments to meet the demand for the consumer segment?

Wireless substitution and cable competition have taken a toll on most wireline carriers' customer base, leading to challenging economics and limited funds for fiber deployment. Wireline telecom carriers have sustainable market share in areas in which they offer fiber to the home.[35] However, the lack of homes passed by upgraded wireline telco broadband (fiber or advanced copper DSL) causes declines in voice and broadband market share versus cable competition.

On average, wireline telecom carriers account for about 37 percent of consumer broadband customers compared to 63 percent for cable.[36] In 2012, telecom companies enjoyed 44 percent broadband market share.[37] Cable competition drives the majority of market share loss. However, small, but persistent pressure from alternative providers that address the most attractive markets where they face low entry barriers also challenge telecom market share. Wireline carriers fare far worse in voice because of wireless substitution. Wireline carrier market share of voice revenue has declined from 79 percent in 2005 to less than 15 percent in 2015, most of which has migrated to wireless only.[38]

This dramatic customer attrition may result in challenging financials for the wireline telecom industry. Current and forward-looking financials leave little room for fiber upgrades. Examining the revenue waterfall in Exhibit 7 demonstrates that post obligations such as debt and interest, wireline companies generate insufficient cash flow to re-invest in fiber to support residential broadband, business services or wireless densification.

Exhibit 7
Average 2016 wireline financials[39]
(iIn thousands of dollars)



After fulfilling obligations such as debt and interest, wireline companies do not generate sufficient cash flow to re-invest in fiber to support residential broadband, business services, or wireless densification.

Carriers have a limited business case for fiber deployment

Based on industry interviews, the costs for telecommunications companies to deploy fiber in urban and suburban geographies has traditionally been between $600 and $1,800 per home passed, excluding customer premise equipment (CPE).[40] Carriers incur and additional 20–30 percent to connect and install a customer.

Carriers typically deploy fiber in four select situations in which they can generate a positive business case. Collectively, these four reasons account for most of the fiber already built that comprises almost the 26 million houses passed.[41] Fiber build motivations under the current industry construct include:

Short investment payback period
Emphasis of deployment to houses and businesses where loop lengths and line make-up allow for relatively inexpensive fiber deployment costs. These include more densely populated areas and aerial (versus buried) environments that offer shorter payback periods on the initial investment.

New build
Carriers typically deploy fiber, in lieu of copper, to serve newly constructed neighborhoods. Labor costs for burying fiber and installing the electronics constitute a vast majority of the deployment costs, implying that the cost of deploying fiber to a new house is about equal to deploying copper. New build US houses grow at approximately 1.5 percent per year (average since 1955),[42] a rate insufficient to address the fiber shortage or coverage of existing houses.

Re-build
Each year, storms and other natural events cause damage to wireline networks. If the required repairs are extensive enough, carriers opt to totally rebuild the network and replace existing copper with fiber.

Subsidized geographies
Federal Universal Service Fund supports fiber deployment in geographies not covered by broadband and where deployment and operational costs are prohibitive. Through August 2015, ten carriers accepted a total of $1.5 billion per year from the Connect America Fund (CAF) to serve approximately 7.7 million Americans.[43]

Carriers fund as much FTTH as possible using a combination of the approaches described above. However, limiting fiber deployment to these motivations leaves the United States dramatically short on high-speed broadband coverage to service broadband and wireless densification.

Carriers today typically deploy fiber in four specific situations in which they can generate a positive business case, given the industry's current structure.

Why broadband Universal Service is challenging

The concept of universal service for voice is relatively simple, as customer needs do not materially change over time. Broadband is much more complex as it has speed, availability, error rate and latency characteristics. In the past, government has set minimum speed characteristics for broadband. However, these minimum performance expectations have changed numerous times over the past 15 years, adding uncertainty to carrier investment decisions. Exhibit A below shows the changes to the FCC's definition of broadband downlink speeds.

Exhibit A
FCC Broadband Speed Definition[61]

Dates	Broadband speed definition
1996–2003	200 Kbps downlink
2004–2010	Measured broadband in five speed tiers ranging from 200Kpbs to 100Mbps
2011–2014	4Mbps downlink/1Mbps uplink
2015–Present	25Mbps downlink/3Mbps uplink

In any universal service approach, defining minimum performance thresholds and future proofing investments is key to providing services. However, government minimums could potentially risk restricting the technologies deployed and how they evolve to meet the changing needs of customers. Market mechanisms that enable robust broadband competition are better equipped to help ensure that performance evolves to meet demand.

Excessive operating expenditures caused by legacy network operations restrict carriers' ability to leverage IP networking advancements

Retirement of legacy TDM networks would greatly reduce operating expenses, freeing up funds for fiber investment.

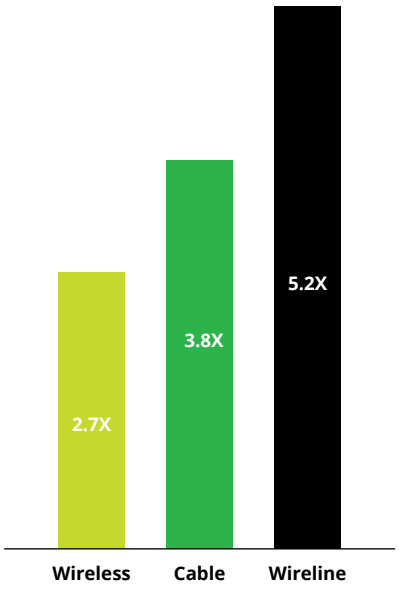
Motivating carriers to fund fiber infrastructure likely requires a method to improve carrier margins and free up money for capital investment. As market share losses in both voice and broadband access mount, carriers have been aggressive in slashing costs. However, cost reduction opportunities are fundamentally limited without an ability to completely retire legacy TDM products and assets. Without the ability to shutter real estate and decommission support systems entirely, cost cutting alone cannot keep pace with customer loss and corresponding revenue declines. As legacy TDM wireline networks continue to descale, the percentage of fixed costs overwhelms the cost structure which could lead to even greater margin pressure.

Carriers are willing to invest in, and could potentially gain tremendous efficiency from deploying new IP networking architectures like Software Defined Networks and Network Function Virtualization (SDN NFV). However, the requirement to operate and maintain legacy TDM-based networks limits carriers' ability to take advantage of the savings and shift capital to deep fiber deployment.

The ratio of cash OPEX to CAPEX in Exhibit 8 depicts the predicament of operating a legacy network given ongoing market share loss. Operating two networks (legacy TDM and IP) forces the largest wireline carriers to spend, on average, five to six times as much on operating expenses as they do capital expenditures. High operating costs due to maintenance of legacy products and systems consume the vast majority of service revenues, leaving less for capital expenditures.

Wireline carriers have both a capital intensive and labor-intensive business model. Other labor-intensive industries such as construction, hospitality and agriculture typically have capital intensities below 5 percent compared to a typical wireline telecom carrier with the expected capital intensity of 14–18 percent.[45] Shifting OPEX dollars to capital investment in fiber deployment requires that carriers operate one network instead of two. Retirement of legacy TDM networks could greatly reduce the operating expenses to free up funds for fiber investment. TDM retirement also frees up capital previously reserved for maintenance of the legacy networks and systems.

Exhibit 8
2016 Average OPEX to CAPEX ratios[44]



Carriers and policymakers can share the responsibility for motivating investment in fiber infrastructure

Carriers and policy makers share responsibility for motivating investment in fiber infrastructure. It is important to attract broadband infrastructure investment from both operators and investors. However, the current economic equation for fiber deployment is driving operators to invest in other areas, or not at all. Failure to motivate investment in deep fiber will likely have three disastrous consequences:

- No network densification to support 5G and associated use cases.
- Lack of choice on providers of consumer broadband.
- Widening of the digital divide.

The current economic equation for fiber deployment is driving operators to invest in other areas, or not at all.

Building a business model based on simplicity and capital productivity can help motivate wireline carrier fiber upgrades

Migration from TDM to an all IP Network improves carrier cost structure by rationalizing product iterations, simplifying processes and drastically reducing IT costs. Moreover, without TDM retirement, IP products must interact with legacy IT systems that complicate selling, provisioning and billing processes. This complexity generates high failure rates and order fall-out, resulting in increased cost for the carrier and inadequate customer experience. Exhibit 9 shows the difference in failure rates and other operational metrics between IP wireline services and mobile services (for example, wireline customers call their carriers twice as frequency as a mobile customer). The ability to retire TDM services and operate an all-IP network would make IP metrics more comparable to mobile metrics and yield significant cost savings and margin benefits.

Eliminating the dependency on the legacy network can help rectify process failure rates. TDM retirement greatly simplifies carrier products, processes and IT. Operating an all-IP network enables more efficient sales, service delivery and service assurance processes through digital channels. Order to cash processes are no longer encumbered by inflexible and dated systems that render inaccurate or inconsistent data, leading to redundant data collection, time-consuming order reconciliation and inefficient process hand-offs. These legacy OSS systems are inherently linked to the TDM network and severely inhibit the opportunities for wireline carriers to realize the cost savings and customer service benefits. Moreover, committing capital to maintain compulsory legacy TDM networks leave minimal ability to fund new IP fiber builds and other access innovations.

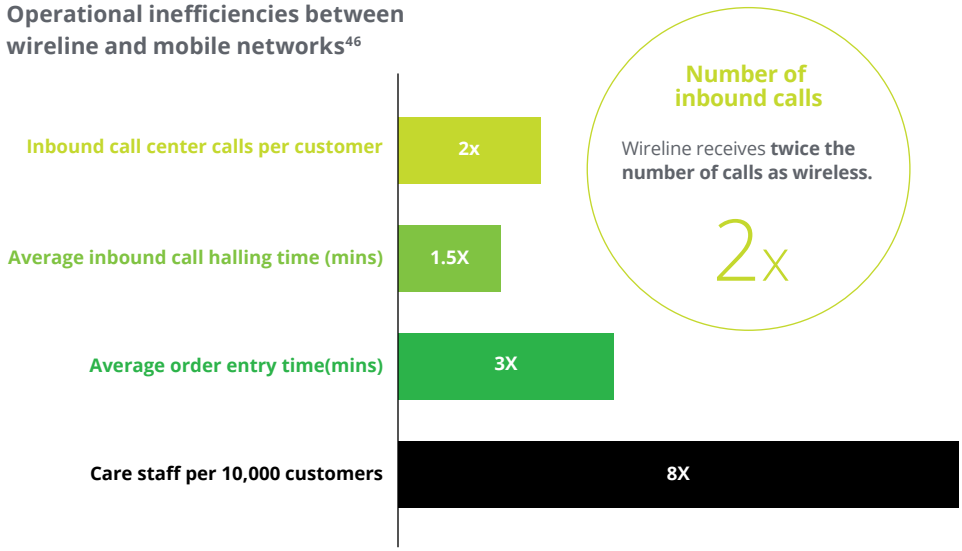
Eliminating the need to accommodate legacy infrastructure and services could also allow carriers to reap efficiency gains from new networking architectures like SDN and NFV. Virtualized network functions are already being implemented in certain parts of the network, like the mobile core, or using virtualized IP platforms for voice services. The savings efficiency of these topologies are limited if workforce processes still are required to maintain legacy systems when highly automated processes could be used if the services were offered on IP.

One study showed that there is a 60–80 percent reduction in real estate and power costs. Migrating to a fiber-based IP network allows carrier to remove equipment, repurpose floor space and even consolidate central offices.[47] A survey conducted by Nemertes Research provides indicative savings from a shift to a single, all IP network:[12]

- Reduction in the average time to repair from 21 hours to 5 hours.
- Increased availability of replacement parts, as some participants complained that replacement parts could only be found using online exchanges due to the age of their systems.
- Reduced equipment maintenance expenses by 34 percent.
- 31 percent lower costs related to moves, adds and changes.

French wireless and wireline provider, Iliad, provides another salient example of operational and cost structure changes feasible when operating an all-IP network and adopting a digital customer experience. In 2015, Iliad operated a $5 billion dollar company with 17.8 million subscribers with only approximately 6,000 employees, while the traditional wireless and wireline carriers operate with approximately 12–15 employees per 10,000 customers, Iliad operates with efficiencies much more aligned with large Internet companies at approximately 3 to 4 employees per 10,000 customers.[13,14]

Exhibit 9
Operational inefficiencies between wireline and mobile networks[46]



Carrier actions to motivate IP migration and fiber deployment

Carriers can enhance their ability to realize cost saving by adhering to a transformation program that creates industry standards for IP product mapping, invests in digital processes, and re-invests savings into deep fiber and/or wireless broadband.

IP product substitution

As addressed in previous sections, discontinuing legacy products is a prerequisite for increased fiber investment. However, legacy product retirement also creates inconvenience for customers. To ease the transition for customers, carriers can work together to create standard product substitutes that meet customer needs. Coordinating the mapping for legacy products to IP catch products among wireline carriers can help gain buy-in from business and residential customers and minimize the time and potential hassle of switching. Carriers can use various industry forums or consortiums to assign a standard IP product replacement for each legacy product and validate their suitability. When determining IP product replacements for TDM, it is important to note that many features from older technologies are obsolete. Therefore, duplicating prior product capabilities and interfaces should not be a requirement.

Carriers can also help ease customers' transition to IP by limiting the number of customer visits or service disruptions. This is especially important when dealing with business customers that likely purchase numerous legacy products from a single carrier. Carriers should carefully craft migration plans that transition entire customers. The alternative of transitioning one product at a time risks numerous customer touches and service outages for a customer. This is understandably more complex with regards to enterprise and carrier services given the diversity of services and products and complexity of contracts.

Investing in digital sales and care channels

Digital transformation in an all IP world has the potential to yield the cost and revenue synergies that generate cash for fiber investment. By taking a synchronized approach, carriers can reap benefits in the front and back end of the digital transformation. Specifically, carriers can better serve customers by improving service metrics and customer experience. Moreover, carriers can generate IT savings by rationalizing applications and test environments, leading to faster product development and provisioning cycle times.

Deployment of competitive broadband to 100 percent of serving area

A profound and impactful action by carriers would be reinvesting the cash generated from the IP and digital transformation to build deep fiber. Carrier benefits include subscriber and revenue growth from broadband as well as access to wholesale backhaul revenue from wireless densification. Potential implications for the nation are nothing short of transformational to our nation's connectivity infrastructure including achieving the fiber density required for 5G wireless services, closing the digital divide and inspiring the next round of innovation.

Given the long timeframes required to reach full fiber deployment, carriers should consider taking advantage of shorter-term alternatives in select markets. In rural areas, fiber to the node, HFC, satellite, or fixed wireless LTE or 5G may bring the best alternative for broadband speeds. Many of these solutions will require deeper fiber deployments to allow access points located within range of the subscriber. However, the case for network investment becomes more difficult as wireline carriers lose broadband market share. Payback periods vary greatly based on a carrier's position in the market, and its ability to transition customers from copper to fiber (versus winning customers away from the competition).

Carriers that act on these principles will likely realize the potential benefits of growth and innovation. Carriers that fail to act quickly risk degradation of their subscriber base to a point that negates the benefits of transformation.

Carriers that take these actions quickly will be able to realize the benefits of growth and innovation

A policy environment more favorable to IP migration will motivate deep fiber investment

Many countries, including the United States, prioritize ubiquitous affordable broadband as a policy objective. The United States ranks tenth in the world for average broadband speed and the percentage of users with over 25 Mbps.[16] This is a remarkable achievement as the United States has almost six times the land area of the countries ranked above it. In many countries, there has been significant government intervention responding to perceived market failure. However, much of the intervention has focused on customer segments and geographies where the market would have likely deployed broadband regardless of government subsidy.

Removing or reducing legacy regulations that constrain competition and investment could enable market forces to solve many of the deep fiber and broadband coverage challenges in the United States Furthermore, empowering market forces could also allow the government to focus on a more limited set of geographies that are very expensive to serve or have low income / affordability issues.

Exhibit 10 references regulations relevant to the country's ability to lead in 5G and bring fast, affordable broadband to more citizens. Examples include carrier of last resort obligations, regulations that prevent carriers from migrating customers to more cost effective IP or wireless solutions by mandating the maintenance of legacy networks and products, and requiring a lengthy process for access to network support structures.

Exhibit 10
Regulations that prevent IP migrations

#	Name	Jurisdiction	Description
1	**Carrier of Last Resort (COLR)48**	Federal/State	• Carriers designated as COLRs must ensure service is available for consumers before they are able to discontinue service, even when there are alternative and competitive options • State commissions have the right to waive this requirement, as a result 25+ states have removed COLR as of 2015
2	**Copper retirement and competing exchange carriers 180-day petition[49]**	Federal	• Requires public notice of network changes that would affect a competing carrier's performance or ability to provide service • Competing carriers have the right to petition the FCC for reconsideration of approval of the changes for 180 days • ILECs must inform customers when copper is being removed from those customers' premises
3	**FCC approval to discontinue service[50]**	Federal	• ILECs require a 60-day review by the FCC for discontinuance of services • FCC requires ILECs to maintain networks at full capacity until retiring
4	**Wholesale services[51]**	Federal	• To discontinue wholesale services, ILECS must file an application under Section 214 of the Communications Act stating that "reasonably comparable" services exist after transition
5	**Marketing limitations[52]**	Federal	• Technology transition rules forbid ILECs from promoting/ marketing to customers to switch to an all-fiber service that is different from their current service
6	**Legacy Compatibility[53]**	Federal	• Requires ILECS maintain service compatibility with a defined list of legacy service for consumers and small businesses, including home security systems, medical monitoring devices, credit card readers and fax machines
7	**Access to poles and conduit[54]**	Federal	• In order to add new cables to a utility pole, each company that owns cables on the pole has to send out technicians sequentially to move existing cables (process can take several months) • Utility providers charge rental rates/tariffs that are almost 2x the cost of network construction
8	**Requirements of traditional service requirements on VoIP[55]**	Select States	• Many states are considering to shift existing telephone rules (discontinuance, notification, 911 integration, etc.) to the VoIP Service providers—done on a state-by-state basis
9	**Replacement of public switched telephone network[56]**	Select States	• Requires telecom providers to conduct education and outreach before seeking withdrawal of circuit switch with confirmation from client party • Requires that alternative telephone service is available before switch • Cannot remove or transition before Jan 1, 2020

Operational efficiencies to disperse universal service support will likely drive faster fiber deployment

Reforming USAC's internal operations seems warranted in order to meet the broader goals of expanding fiber infrastructure and addressing rural Internet access.

Encouraging innovation and network reinvestment in deep fiber by removing legacy technology and administrative obstacles may assist carriers in their efforts to retain customers and generate the cash flow needed to strengthen their networks. To help meet ambitious fiber deployment goals, it makes sense to evaluate both the objectives and operations of the Universal Service Fund (USF) and its Administrator. Reforms to the Universal Services Administrative Company (USAC) to improve operational efficiency is a prerequisite to implement a coordinated deep fiber program that can help drive densification and broadband competition.

The FCC and Congress set policy objectives for the USF. Success regarding USF policy objectives relies on the operational effectiveness of USAC. However, USAC has come under growing criticism from multiple areas regarding its operations and the resulting impact to end-users, such as schools, libraries and private companies. In one case, USAC asked for records going back 15 years to 1998 before it would fund infrastructure build. More recently, the FCC reversed USAC's imposition of late fees and penalties based on contribution amounts that had been reversed; USAC imposed fees and penalties that were over twice the underlying contribution amount and took 17 years to resolve.[58]

Education Week's May report states "In recent weeks, according to school-broadband advocates, more than 100 school districts have received letters questioning their plans to use federal E-Rate funds to support construction of fiber-optic networks. The new inquiries, however, have prompted more uncertainty to bring high-speed Internet to some of the country's hardest-to-reach students." While these stakeholders are expressing frustration, it has been particularly galling for some to see the USAC's internal expenses grow at approximately 12 percent per year on average.[17] Consequently, it is no surprise that USAC's internal implementation of some of these programs has also recently received scathing FCC criticism. Chairman Pai criticized cost overruns and failure to meet FCC deadlines[FN]. And as Commissioner Michael O'Reilly wrote, "The departure of its CEO presents an opportunity for the Universal Service Administrative Company (USAC) to clean up its act[FN]."

In 2005 and again in 2008, the FCC considered putting USAC's operations out for competitive contract to save costs and improve responsiveness to organizations seeking funds to close the digital divide.[59] There is, in fact, precedent in government putting specific operations out to bid or prompting competition. For example, the numbering administration has been successfully run by commercial firms for over a decade. A dozen years later, given the critical role of broadband to our country's economy and the imperative that our country lead in 5G, USAC reform is more important than ever. At minimum, reforming USAC internal operations seems warranted to meet broader goals of expanding fiber infrastructure and addressing rural Internet access.

Conclusion

Increased fiber investment will require new monetization mechanisms

Fiber passes less than one third of US houses. Only 39 percent of consumers have access to more than one broadband provider of 25 Mbps service.[6] Vast discrepancies in choice, affordability and performance still exist between rural, underserved and urban geographies. Wireline broadband in the form of deep fiber and DOCSIS cable are paramount to unleashing wireless innovation, IoT functionality, immersive entertainment and functionality yet imagined.

However, the future of connectivity in the United States remains uncertain. IP migration and regulatory reforms could help, but may be insufficient to motivate deep fiber deployment that meets broadband and densification needs.

Telecommunications companies are choosing to invest in areas other than fiber deployment including satellite TV, advertising, content and advanced business services. Similarly, while infrastructure funds and REITs have invested heavily in asset-based businesses, there have been very few investments by these players in telecommunications assets. The result of this lack of investment shows in the asset bases of the carriers, many of which are depreciating more than they invest each year. Typically, wireline companies depreciate about 1.2x–1.3x as much PPE as they add in a given year.[9]

Wireless, wireline and cable require new methods to monetize last mile access to provide incentive for massive fiber deployment. We contemplate three potential models: adjacent services, ecosystem participation and the last mile as a real estate play. Each capitalizes on the few, but important certainties in the future of connectivity including device proliferation from IoT, massive traffic growth and limited gains in yield (i.e. revenue per MB).

While infrastructure funds and REITs have invested heavily in asset-based businesses, there have been very few investments by these players in telecommunications assets.

Model 1

Synergies between deep fiber and adjacent services in an 'unlimited' world

Gartner predicts that affluent households will have up to 500 connected devices by 2022.[17] The number of devices and associated services provide an opportunity for carriers to grow ARPU beyond flat fees for unlimited bandwidth. According to Deloitte's 2016 Global Mobile Consumer Survey, 75 percent of surveyed consumers indicate an interest in home based IoT applications, while approximately 65 percent and 62 percent of surveyed consumers indicate an interest in automotive and wearables respectively. In some cases, IoT services offer the prospect of new revenue, however most connected devices will likely require low bandwidth or will likely be WiFi enabled and, therefore, may not provide carriers with incremental revenue. In such cases, carriers have an opportunity to increase revenue by offering integration, network security, and traffic management services within the increasingly complex mix of IoT devices and ecosystems. Most users want seamless performance despite devices using a mix of communications technologies. Relationships between hundreds of IoT devices and users are complex; most households or businesses have multiple occupants, making linkages between devices and environments difficult. Carriers are well positioned to solve IoT integration needs.

Why rural broadband is more of a challenge in the US than abroad

It is clear that the digital divide is prevalent between urban and rural America, shown by the increasingly uneven access to broadband. But is this trend isolated to just America? How are countries with more of a rural population handling the lack of broadband access?

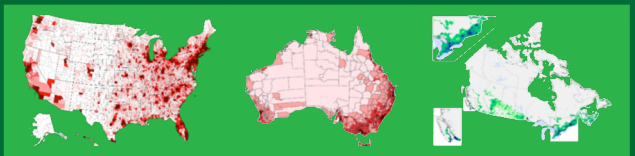
Examining Australia and Canada provides an interesting contrast; although both countries have much lower population densities than the United States (2.91 and 3.49 vs 32.45 people/km^2),[60] the population in both Australia and Canada is significantly more geographically concentrated than in the United States.

This means that the countries face a very different set of challenges. Australia and Canada can get to 90 percent+ of fiber coverage by covering 4 percent (325,000 km2) and 3 percent (335,000 km^2) respectively. To fulfill the same objective in the United States, the coverage required is 31 percent (2,895,000 km^2). Given the variances in population concentration, the feasibility of the national fiber network akin to NBN in Australia is far more cost prohibitive for the United States.

The main challenge for the United States is the significant area and percentage of population live in low (5–50 people per square km) densities. These low density areas are half the total United States area but less than 5 percent for Canada or Australia. It is these densities where the deployment economics get very challenging.

Therefore, it is important that the United States address its rural broadband needs with a variety of alternative technologies such as satellite, wireless solutions, cable, alternative copper (vectoring, advanced DSL) and fiber. Access technology should be based on market needs and cost structure for a particular geography, versus regulatory mandate or prescription.

Exhibit B
Population densities in three countries[60]



Percent of population	Percent of land area		
	United States	**Australia**	**Canada**
60%	8.7%	0.2%	0.5%
80%	20%	0.9%	1.2%
90%	31%	4.2%	3.3%
Land area	**Low density (5–50 people per km^2) challenge**		
Percent of population	37%	18%	14%
Percent of land area	48%	4%	1.4%

Model 2

Partnership between carriers and OTT players to fund deep fiber

Technology and over the top players have incentives to encourage deep fiber deployment. Many depend on a growing population of end users having sufficient bandwidth to access their services at home, in the office, and on the go. As the disparity grows between the fiber available and the need for additional wireless densification and fiber broadband, over the top players may choose to fund fiber deployment. Funding can take the form of asset ownership or partnerships that provide funds to carriers for fiber builds in exchange for debt or equity. Regardless, it is difficult to meet objectives for deep fiber deployment without funding from players that constitute a large percentage of revenue from Internet-related services.

Model 3

Deep fiber a financial investment

Insufficient supply of deep fiber and overwhelming demand growth characterize today's communications market, making the fundamentals strong for fiber investment. As regulatory, technology and financial hurdles abate, the case for investment strengthens for financial players such as REITs and Communications Vendors and Tower Companies.

For example, increased use of high frequency spectrum requires that in-building network coverage receive special attention. Fiber resident in building risers offers coverage and capacity solutions for carriers. Building owners and/or REITs can monetize existing or new fiber assets through carriers or offer their own services to end users. Building owners can also extend their fiber assets to provide backhaul for outdoor small cells. This is just one example of how financial or other non-traditional players can invest to help fill the fiber gap.

As investment interest grows from non-traditional fiber investors, we can anticipate shared infrastructure to play a more prominent role in last mile fiber access. Wireless providers began by building and maintaining their own towers. However, as network coverage, capacity and speed became the bases of competition, they quickly switched to a more efficient, shared asset model for their physical infrastructure. Tower companies provided a mechanism for wireless carriers to share physical infrastructure while maintaining control of their radio access networks (RAN), providing significant synergies in real estate and maintenance costs.

The same opportunity may apply to deep fiber. Treating fiber as a real estate investment leased to multiple carriers to maximize asset utilization can provide a mechanism for carriers to potentially reduce operational costs and help minimize capital requirements. High asset utilization combined with ecosystem monetization discussed above can provide investors with attractive returns. Financial investors or tower companies should consider deep fiber investment in tandem with carriers to achieve faster monetization and further secure returns.

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